**Interference in Thin Films**

Review

Wave Equation: **ν = *f*λ**  **ν:**

***f*:**

**λ:**

**Refraction**: A wave bends as it travels between two media with different speeds. The more the wave has to slow down (or speed up), the more it bends.

Sound travels faster through dense media. For example, sound travels faster through a solid (like a desk) than it does through a liquid or gas (like air).

Light does the opposite: Light travels slower through more optically dense materials. Optical density is not always the same as physical density, however, since unlike sound, light does not penetrate all media.

The **index of refraction** of a medium **(n)** is a measure of the optical density of a medium. A medium with high index of refraction will slow light down a lot. The index of refraction of a medium is given by:

**n = c/v**

Note:

c = 3.00 x 108 m/s, the speed of light in a vacuum

ν is the speed of light in the material.

It is impossible to go faster than the speed of light in any medium, so n is always greater than 1.

A light ray that goes from a fast medium (n = 1) to a slow medium (n>1) will bend toward the normal (line perpendicular to surface).

i.e.

air (n=1.00)

glass (n=1.52)

The bending of a wave as it passes from one medium to another is called **refraction**.

Consider a wave travelling from air into another medium. In this case, the frequency of the wave is fixed (it is set by the source creating the wave)



This means the wavelength of the wave changes as the speed changes. The new wavelength can be calculated with the formula:

ν = λ*f*

Examples:

1. A pulse of blue light is passed from air into diamond (c = 2.45). What colour is the light in the diamond?
2. Monochromatic light with a wavelength of 650 nm, in air, travels into a piece of glass where it is slowed down to a speed of 1.95 x 108 m/s. What is the wavelength of the light in the glass and what is the glass’ refractive index for this light? (1 nm = nanometer = 10-9 m)

Partial Reflection - Partial Transmission

When a wave travels from one medium to another, part of the wave is transmitted into the second medium while part of it is reflected back into the first medium. If the wave travels slower in the second medium, the reflection will be inverted - it will undergo a phase change of 180°.

incident pulse

incident pulse

i.e.

reflected pulse

slower

medium

faster

medium

slower

medium

faster

medium

reflected pulse

Combine this with refraction...

When a vertical soap film is viewed perpendicularly, under white light, a spectrum of colours is seen. This occurs as a result of interference between the rays reflected from the top and bottom surfaces of the film.

air (faster)

air (faster)

film (slower)

air (faster)

air (faster)

film (slower)

If the film is thin, then the two reflected rays will reach your eye at the same time and interfere.

The part of the ray that is transmitted will reflect at the bottom surface of the film. Since it goes from the film to the air, this reflection will NOT be inverted.

The ray will undergo partial reflection - partial transmission. The ray reflected at the top surface of the film will be inverted.

**Note**: For clarity, the rays are shown entering at an angle of incidence ≠ 0° but in reality all rays travel perpendicular to the film (straight up and down).

The thickness of the soap film is **t**. The reflection from the bottom surface of the film, compared to the reflection at the top surface, has to travel an extra distance of **2t** before reaching your eye.

air

air

soap

t<<λ

t

path difference is \_\_\_\_\_\_

Destructive interference

air

air

soap

path difference is 



Constructive interference

air

air

soap

air

path difference is λ



Destructive interference

**Note:** the λ corresponds to the wavelength of light in the film, not in air.

Examples

1. A horizontal soap film, n = 1.35, has a thickness of 80.0 nm. If it is viewed perpendicularly under white light, then what colour is strongly reflected?

Eyeglasses and lenses are coated with a thin film to reduce back-glare, an effect occurring when light is reflected from the back of the glasses into the eyes. The refractive index is about midway between the refractive indexes for air and the glass. The wavelength usually chosen is close to the midpoint of the visible spectrum (550 nm). Since the reflected light near the violet and red extremes of the spectrum is not reduced very much, the surface of the lens can appear purple.

1. A camera lens (n = 1.51) is coated with a thin film with a refractive index of 1.25. What should be the minimum thickness of the film to minimize reflected light with a wavelength of 550 nm?

air (n=1.00)

coating (n= 1.25)

glass (n=1.51)